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Journal

OTA International The Open Access Journal of Orthopaedic Trauma, 6(4)

ISSN

2574-2167

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Publication Date

2023-12-01

DOI

10.1097/oi9.0000000000000289

Peer reviewed

Clinical/Basic Science Research Article

OPEN

MELD score predicts short-term outcomes after surgical management of proximal humerus fractures: a matched analysis

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Abstract

Objective: We aimed to evaluate the difference in 30-day outcomes after surgical management of proximal humerus fractures (PHFs) between patients with and without chronic liver disease as defined by a MELD score greater than 10.

Design: This was a retrospective database review.

Setting: All centers participating in the American College of Surgeons National Surgical Quality Improvement Program database were included.

Patients/Participants: Patients with proximal humerus fractures who (1) underwent ORIF, HA, or SA and (2) had calculable MELD scores were included.

Intervention: Open reduction and internal fixation, hemiarthroplasty, or shoulder arthroplasty was used for treatment.

Main outcome measurements: Thirty-day complications, mortality, readmission, and reoperation rates were measured.

Results: Of the total 1732 PHF patients identified, 300 had a MELD score higher than 10. After propensity matching by significant covariates, MELD score higher than 10 was found to be significantly associated with higher rates of 30-day mortality, 30-day readmission, transfusion within 72 hours, and systemic complications. Among patients with a MELD score higher than 10, treatment with SA or HA instead of ORIF was associated with a higher rate of transfusion and longer operative time. There were no significant differences between treatment cohorts regarding mortality, reoperation, readmission, or complications.

Conclusions: A MELD score higher than 10 is associated with higher risk of surgical complications, transfusion, and death in patients undergoing surgery for proximal humerus fractures. Among patients with a MELD score higher than 10, ORIF was associated with a lower transfusion rate and shorter operative time than arthroplasty or hemiarthroplasty.

Level of Evidence: Prognostic Level III.

Key Words: proximal humerus fractures, chronic liver disease, shoulder arthroplasty

1. Introduction

Proximal humerus fractures (PHFs) are the third most common geriatric fragility fracture.[1,2] The incidence of geriatric proximal humerus fractures is expected to increase in parallel with the increased life expectancy of the American population. While many geriatric PHFs may be treated nonoperatively, complex 3 or 4-part fractures with substantial displacement may be indicated for surgical management.[2,3] To improve patient outcomes and minimize harm, it is critical to define appropriate surgical candidates and thoroughly characterize risk factors that portend poor postsurgical outcomes after surgical management of PHF.

One specific risk factor of interest is chronic liver disease (CLD). Owing to increasing rates of metabolic disease and IV drug use, the prevalence of CLD has increased over the past decade in the United States.[4,5] Not only have the numbers risen but the CLD patient population has become older on average,[4,6] putting them at increased risk of sustaining geriatric fragility fractures such as hip fractures, distal radius fractures, and proximal humerus fractures.

The Model for End-Stage Liver Disease (MELD) score was developed to predict survival and help prioritize liver allocation to transplant recipients.[7] It is easily calculated based solely on 3 laboratory values (bilirubin, creatinine, and international normalized ratio (INR)), and a threshold of 10 is used to define patients with none-to-mild liver disease and those with moderate-to-severe liver disease.[8,9] Prior studies focusing on total joint arthroplasty[10] and hip fracture surgery[11] have shown that MELD score is significantly associated with short-term surgical complications and mortality in orthopaedic patients. Tiberi et al[10] reported that total joint arthroplasty patients with a MELD score

Funded in part by the H&H Lee Surgical Research Scholars Grant.

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The authors report no financial disclosures or conflicts of interest related to the current work.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.otainternational.org).

OTAI (2023) e289

Received: 23 February 2023 / Accepted: 21 September 2023
Published online 27 October 2023

http://dx.doi.org/10.1097/OI9.0000000000000289

greater than 10 had three-fold higher risk of any postsurgical complication and four-fold higher risk of mortality. However, there is a paucity of literature characterizing outcomes after surgical management of PHF in this patient population. Furthermore, in patients with CLD who require PHF surgery, there is little evidence regarding the relationship between treatment modality and perioperative outcomes. Shoulder arthroplasty has become an increasingly popular option for complex PHF,[12,13] but its potential association with surgical complications in this high-risk population remains unknown.

This study aimed to use a propensity-matched data set to evaluate the difference in 30-day outcomes after surgical management of PHF between patients with and without CLD as defined by a MELD score greater than 10.

2. Materials and Methods

The patient sample for this study was acquired from the American College of Surgeons National Surgical Quality Improvement (NSQIP) database over a 10-year period (January 1, 2010, to December 31, 2019). The NSQIP database collects procedural details, diagnoses, patient characteristics, comorbidities, and postoperative outcomes up to 30 days after the index surgery. It has been extensively validated as a reliable tool for assessing short-term surgical outcomes.[14] Because the NSQIP database is deidentified of patient-specific identifiers, this study was deemed exempt from institutional review board review at our institution.

The database was queried for all adult patients who sustained a PHF and underwent ORIF, HA, or SA (total shoulder arthroplasty or reverse total shoulder arthroplasty). Inclusion criteria were 18 years or older; diagnosis code corresponding to proximal humerus fracture; procedure code corresponding to ORIF, HA, or SA; and preoperative values recorded for serum bilirubin, INR, and creatinine—the 3 components required to calculate the MELD score.

The International Classification of Disease, Ninth Revision (ICD-9) codes 812.0 and 812.1 were used to define PHF in patients before October 2015 while the ICD-10 code S42.2 was used to identify patients after October 2015. Current Procedural Terminology (CPT) codes 23615 (ORIF), 23616/23470 (HA), and 23472 (SA) were used to define the operative method. The Model for End-Stage Liver Disease (MELD) score was calculated for all patients using the following formula: $3.78 \times \text{Ln}$ (serum bilirubin in mg/dL) + $11.2 \times \text{Ln}$ (INR) + $9.57 \times \text{Ln}$ (serum creatinine in mg/dL) + 6.43, whereby Ln refers to natural log and INR refers to the international normalized ratio.

Demographic and comorbidity variables were collected, including age; sex; race; ethnicity; body mass index; American Society of Anesthesiology (ASA) score; diabetic status; smoking status; and history of chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), myocardial infarction (MI), hypertensive medication (HTN), or chronic immunosuppressant or steroid use. Surgical details including type of anesthesia and elective versus nonelective case status were collected. In the NSQIP database, elective surgeries are defined as those where the patient presented from home. Patients were stratified into 2 cohorts based on existing liver surgery literature[8]—MELD score less than or equal to 10 or MELD score greater than 10.

The primary outcomes of interest were operative time; length of stay; and presence of any short-term adverse outcome including 30-day mortality rate, 30-day reoperation rate, 30-day readmission rate, major systemic complications, minor systemic complications, and wound complications. Major systemic complications included sepsis, septic shock, pulmonary embolism (PE), failure to wean from ventilator for more than 48 hours postoperatively, pulmonary distress requiring reintubation, renal failure, myocardial infarction (MI), and stroke. Minor systemic complications included pneumonia, deep venous thrombosis (DVT), urinary tract infection (UTI), and renal insufficiency. Wound complications included superficial infection, deep wound infection, and wound dehiscence. Any adverse outcome was defined as the presence of one or more of the above complications.

Propensity score matching is a statistical tool that minimizes selection bias when estimating treatment effects in nonrandomized studies. The psmatch2 module in Stata was first used to compare patients with and without CLD as defined by a MELD score greater than 10. According to published guidelines,[15] all covariates found to be significantly ($P < 0.05$) associated with adverse outcomes on univariate analysis (Table 1) were included as covariates for propensity score matching. Hence, patients with and without CLD were matched 1 to 1 using nearest neighbor propensity score matching without replacement on the basis of the following variables: age, sex, BMI, ASA score, insulin dependence, COPD, CHF, HTN, chronic steroid use, and elective nature of surgery. Post hoc balance assessment was performed to determine the quality of propensity matching. Primary outcome measures were then compared between matched cohorts.

Subgroup analysis limited to patients with a MELD score greater than 10 was performed next. Univariate analysis was used to identify variables associated with adverse outcomes. Next, propensity score matching was performed with significant univariate variables included as covariates to compare patients who underwent ORIF, hemiarthroplasty, or shoulder arthroplasty. Primary outcome measures were compared between matched treatment groups to assess the relationship between the treatment cohort and outcomes of interest in patients with CLD.

Chi-square tests were used for univariate categorical analysis. After assessment of normality with the Shapiro-Wilks test, the Wilcoxon rank-sum test was used for univariate nonparametric analysis. The psmatch2 Stata module was used to perform 1 to 1 nearest neighbor propensity score matching without replacement. Statistical significance was defined as $P < 0.05$ for all tests. All analyses were performed with Stata 12.0 software (StataCorp LLC, College Station, TX).

3. Results

A total of 6953 surgically treated PHF patients were identified in the NSQIP data set, of which 1732 had all MELD score components reported. Of these, 369 patients (21.3%) sustained any adverse outcome postoperatively (30-day mortality, readmission, reoperation, 72-hour transfusion, major or minor systemic complication, or wound complication). On univariate analysis, patients who sustained adverse outcomes were older; had a lower BMI; were more likely to be male; were more likely to have an ASA score greater than 3; were more likely to have insulin-dependent diabetes; were more likely to be taking chronic steroids; and were more likely to have COPD, CHF, or HTN (Table 1). A lower proportion of these patients underwent surgery on an elective basis.

Of these patients, 300 (17.3%) had a MELD score higher than 10. Matching based on all univariate variables associated with adverse outcomes was performed to generate 2 well-balanced cohorts based on MELD score. Thirteen patients did

TABLE 1

Characteristics Associated With Any Adverse Outcome After Surgical Management of Proximal Humerus Fractures

	No Adverse (n = 1363)	Any Adverse (n = 369)	*P*
Age (years)	65.5	72.6	<0.001
Male (%)	23.1	28.5	0.034
Race (%)			0.223
White	80.9	80.7	
Black	2.6	3.1	
Asian/Pacific Islander (PI)	1.8	1.1	
Native American	0.4	0.7	
Unknown	13.4	12.8	
Hispanic (%)	10.4	8.0	0.383
Body mass index	28.6	27.6	0.008
Obese: BMI ≥30 (%)	39.5	34.4	0.077
Underweight: BMI <18.5 (%)	5.9	6.5	0.649
American Society of Anesthesiology (ASA) score of greater than 3 (%)	7.0	19.2	<0.001
Diabetes (%)			0.004
Non–insulin-dependent (NIDDM)	14.5	12.7	
Insulin-dependent (IDDM)	8.8	14.6	
Current smoker (%)	19.4	17.3	0.362
Chronic obstructive pulmonary disease (COPD) (%)	8.5	12.7	0.014
Chronic heart failure (CHF) (%)	1.7	3.8	0.013
History of myocardial infarction (%)	0.3	1.4	0.244
Hypertension (HTN) (%)	62.0	68.6	0.020
Chronic immunosuppressant/steroids (%)	3.5	7.6	0.001
Elective procedure (%)	58.0	37.4	<0.001
General anesthesia (%)	97.3	97.8	0.558
MELD score >10 (%)	13.4	31.7	<0.001
MELD score	8.0	9.5	<0.001

not have information on elective versus nonelective procedure and were excluded from matched analysis, yielding matched cohorts of 287 patients each. Post-match assessment showed that the propensity-matched cohorts were well-balanced (Table 2, Fig. 1).

When comparing the matched cohorts, a MELD score greater than 10 was associated with higher rates of any adverse event (39.4% vs. 21.6%, $P < 0.001$), 30-day mortality (3.1% vs. 0.3%, $P = 0.011$), 30-day readmission (12.9% vs. 7.0%, $P = 0.023$), and 72-hour transfusion (26.5% vs. 13.2%, $P < 0.001$) (Table 3). Patients with a MELD score greater than 10 also had higher rates of major or minor systemic complications, specifically septic shock (1.4% vs. 0.0%, $P = 0.045$), reintubation (1.7% vs. 0.3%, $P = 0.025$), pneumonia (3.8% vs. 1.1%, $P = 0.030$), and renal insufficiency (1.4% vs. 0.0%, $P = 0.045$).

Of the 287 proximal humerus fracture patients with CLD, 156 underwent ORIF, 45 underwent HA, and 86 underwent primary shoulder arthroplasty. On subgroup analysis limited to patients with CLD, age, sex, BMI, ASA score, and elective status were found to be significantly associated with risk of adverse outcomes. Propensity-matched analysis based on these variables was performed to compare proximal humerus fracture patients with CLD who underwent ORIF, HA, or SA.

Patients who underwent SA (31.4%) or HA (46.2%) had higher rates of transfusion within 72 hours compared with matched patients who underwent ORIF (16%–19%). Treatment with HA or SA was also associated with an additional ~40 minutes of operative time than ORIF (Tables 3 and 4). There was no significant difference between treatment groups in mortality rate, reoperation rate, readmission rate, major systemic complications, minor systemic complications, or local complication. See Table 3 for detailed ORIF versus SA results, Table 4 for ORIF versus HA results, and Appendix 1 (http://links.lww.com/OTAI/A88) for SA versus HA results.

4. Discussion

We found that a MELD score higher than 10 is an independent risk factor of 30-day mortality, readmission, postoperative transfusion, and complications after the surgical management of PHF. However, surgical treatment modality was not found to significantly affect short-term outcomes in PHF patients with CLD.

The decision to undergo nonoperative or operative management of PHF is far from clear cut. The ProFHER (Proximal Fracture of the Humerus: Evaluation by Randomisation) trial failed to find benefit from either a clinical or cost-effectiveness standpoint for the surgical management of displaced PHF,[3] and there remains a lack of studies showing that surgical management confers superior outcomes to conservative treatment even in displaced fractures. Still, the number of surgeries performed for PHF has risen over the past few decades and is not expected to slow down.[1] As the US population ages and the number of patients with chronic diseases such as CLD continues to increase, it will be increasingly important to appropriately risk-stratify this high-risk patient population to minimize surgical complications. This study demonstrates that elevated MELD score is a significant independent predictor for poor postoperative outcomes, irrespective of other comorbidities, making it a useful stratification tool when counseling patients on operative versus nonoperative management.

TABLE 2

Characteristics and Outcomes Between Propensity-Matched Cohorts

Event (%)	MELD ≤10 (n = 287)	MELD >10 (n = 287)	P
Characteristics			
Age (years)	70.0	70.0	0.964
Male (%)	34.5	37.3	0.486
BMI	29.1	29.0	0.880
ASA >3 (%)	20.9	20.2	0.836
IDDM (%)	14.3	17.1	0.358
Current smoker (%)	20.3	18.3	0.535
COPD (%)	13.2	12.2	0.707
CHF (%)	3.5	4.9	0.404
History of MI (%)	1.0	1.0	0.189
HTN (%)	78.4	76.7	0.617
Chronic steroid use (%)	9.4	6.6	0.219
Elective (%)	41.8	42.5	0.866
Event (%)	**MELD ≤10 (n = 287)**	**MELD >10 (n = 287)**	***P***
Outcomes			
Any adverse event	21.6	39.4	<0.001
30-day mortality	0.3	3.1	0.011
30-day reoperation	3.8	5.6	0.324
30-day Readmission	7.0	12.9	0.023
72-hour transfusion	13.2	26.5	<0.001
Major systemic complications	1.0	4.2	0.019
Pulmonary embolism	0.0	0.0	NA
Renal failure	0.0	0.3	0.317
Cardiac arrest	0.4	1.1	0.316
Myocardial infarction	0.0	0.7	0.157
Sepsis	0.4	1.7	0.101
Septic shock	0.0	1.4	0.045
Cerebrovascular event	0.4	0.0	0.317
Reintubation	0.3	1.7	0.025
Coma	0.0	0.0	n/a
Failure to extubate 48 hours	0.0	1.1	0.082
Minor systemic complications	3.5	7.7	0.029
Pneumonia	1.1	3.8	0.030
Deep venous thrombosis	1.1	0.4	0.316
Urinary tract infection	1.4	2.1	0.523
Renal insufficiency	0.0	1.4	0.045
Wound complications	0.7	0.4	0.563
Superficial infection	0.0	0.0	n/a
Deep wound infection	0.7	0.4	0.563
Wound dehiscence	0.0	0.4	0.317
Operative time (minutes)	121.4	121.8	0.850
Length of stay (days)	4.2	5.5	<0.001

Although this is the first study to report on the surgical outcomes after PHF surgery in patients with elevated MELD scores, prior studies have evaluated the relationship between MELD score and outcomes in other surgical patient populations. Zielsdorf et al[16] used the NSQIP database to assess the relationship between MELD score and postoperative complications after inguinal hernia repair, umbilical hernia repair, and colon resection, finding that each 1-point increase in MELD score correlated with a roughly 10% increase in any postoperative complication. Elevated MELD score has also been found to be associated with increased morbidity and mortality in patients undergoing infrainguinal bypass[17] or cardiac surgery.[18] In the orthopaedic literature, Tiberi et al[10] found that patients with cirrhosis undergoing total joint arthroplasty were at elevated risk of postoperative mortality, overall complications, blood transfusion, and readmission. They found that patients with a MELD score higher than 10 suffered a higher mortality rate (32% vs. 10%) and surgical complication rate (26% vs. 7%) than those with a MELD score below 10. Finally, Hundersmarck et al[11] assessed 90-day, 1-year, and 2-year mortality rates in patients with CLD who underwent hip fracture surgery and found that increasing MELD score was associated with higher rates of mortality. Compared with the surgical populations assessed above, PHF surgery is less invasive with lower mortality. However, even after this comparatively lower risk surgery, we found that the association between MELD score and increased postsurgical complications remains consistent.

When limiting our analysis to patients with a MELD score greater than 10, we found that patients with CLD undergoing PHF surgery did not have different outcomes whether they underwent ORIF, hemiarthroplasty, or shoulder arthroplasty. While HA and SA were associated with an additional ~40 minutes of operative time and higher risk of requiring transfusion (HA—46.2%, SA—31.4%, ORIF—16%-19%), the rates of 30-

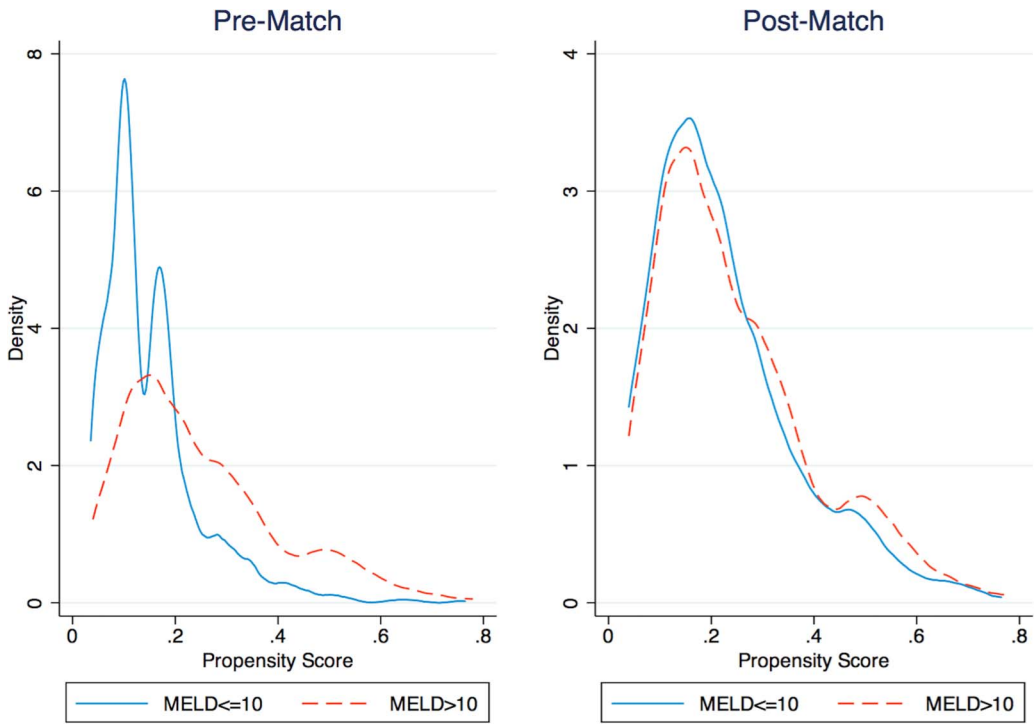

FIGURE 1. Propensity scores between patient cohorts before (pre-match) and after (post-match) propensity score matching.

day mortality, 30-day reoperation, 30-day readmission, or postsurgical complications did not significantly differ between the treatment groups. These findings suggest that while PHF patients with elevated MELD scores are at higher risk overall, the relative complication profile between the 3 primary surgical options is not significantly different.

The ideal surgical option for operative PHF remains highly controversial. ORIF has historically been the most common surgical treatment option, but has been associated with high rates of head collapse and intra-articular screw penetration in the osteoporotic bone found in the geriatric population.[19] HA was a common head-replacing option for complex fractures at risk of osteonecrosis, but reverse total shoulder arthroplasty (RTSA) has rapidly gained traction over the past few decades as a primary treatment option because of its superior patient clinical and functional outcomes compared with HA.[12,20–22] The rise of RTSA has spurred a wealth of literature comparing ORIF with RTSA for short-term complications, clinical outcomes, functional outcomes, and long-term reoperation rates. RTSA has been associated with higher rates of blood transfusion[23] but has also demonstrated superior functional outcomes[24,25] and lower rates of reoperation[26–28] compared with ORIF. While our analysis is limited to 30-day outcomes because of the nature of the NSQIP database, our findings regarding short-term outcomes after PHF surgery in the CLD-specific patient cohort is consistent with trends noted in all PHFs. In short, treatment with primary arthroplasty does not confer a higher risk of short-term complications or mortality compared with ORIF, even in patients with elevated MELD scores. The decision-making process, then, should continue to be based on factors such as fracture morphology, patient age, and patient level of activity.[29,30]

The MELD score was initially developed to predict survival in patients with cirrhosis undergoing transjugular intrahepatic portosystemic shunt (TIPS) placement. Owing to its strong correlation with mortality and disease severity in patients with liver disease, it was also adopted by the United Network for Organ Sharing as a way to prioritize liver allocation to potential transplant recipients.[7] While the MELD score is not the only commonly used prognostic score used to stratify patients with CLD, it has the distinct advantage of relying solely on objective data. Orthopaedic surgeons are unlikely to be facile at evaluating certain subjective variables in the Child-Pugh score such as ascites or hepatic encephalopathy, but the MELD score is easily calculated based on 3 laboratory values—bilirubin, creatinine, and INR. A MELD score threshold of 10 is a commonly used cutoff that dichotomizes patients between those with none-to-mild liver disease and those with moderate-to-severe liver disease.[8,9]

This study does have significant limitations, many of which are inherent to the NSQIP database. The NSQIP database is limited to surgical patients, preventing us from comparing our surgical cohort with a nonoperative cohort to comment on the effect of operative management on modulating mortality risk in PHF patients with CLD. Future studies that compare outcomes after operative versus nonoperative management in proximal humerus fracture patients with elevated MELD scores will help further inform treatment decisions. Furthermore, NSQIP only tracks outcomes up to 30 days after a surgical procedure, meaning this study is unable to comment on adverse outcomes, such as infection or nonunion, that generally occur past 30 days. Finally, while the NSQIP data are abstracted by well-trained nurse reviewers with high inter-rater reliability, the cost of data abstraction prevents many smaller hospitals from joining.[31] This means that the NSQIP database contains a higher proportion of data from large teaching hospitals with more complex patients, limiting the generalizability of our findings.

This study also has limitations shared with all database studies. Because databases do not contain radiographs, operative notes,

TABLE 3

ORIF Versus SA in Propensity-Matched Patients With Chronic Liver Disease

	ORIF (n = 86)	SA (n = 86)	*P*
Age (years)	74.2	73.6	0.719
Male (%)	34.9	38.4	0.635
BMI	30.9	30.1	0.801
ASA greater than 3 (%)	25.6	18.6	0.270
Elective (%)	41.5	53.5	0.119
Any adverse event	33.7	44.2	0.159
30-day mortality	4.7	1.2	0.173
30-day reoperation	5.8	5.8	1.000
30-day readmission	16.7	11.8	0.369
72-hour transfusion	16.3	31.4	0.020
Major systemic complications	3.5	4.7	0.700
Minor systemic complications	12.8	9.3	0.466
Local complications	0.0	0.0	NA
Operative time	97.9	138.4	<0.001

or clinical notes, we are unable to stratify by fracture type or severity and cannot comment on outcomes such as fracture healing, patient-reported outcomes, or patient satisfaction. The retrospective nature of database-driven studies also precludes randomization to treatment cohorts. While propensity score matching has been shown to limit bias to levels seen in randomized trials,[32] propensity score matching can only ensure balance in measured confounders. Variables that are often missing or not included in NSQIP, such as alcohol use and recreational drug use, represent possible unmeasured confounders that may affect the results. Despite using 10 years of the NSQIP data set, when comparing matched cohorts of ORIF, HA, and SA patients, this analysis remains underpowered. A post hoc power analysis using G*Power found that 199 patients per treatment group would be needed to detect a 10% drop in complication rate with 80% power. The logical next step will be to conduct an adequately powered comparative analysis in a few years with additional data and a higher number of SA patients. While MELD scores were only able to be computed for 1732 of 6953 patients who received proximal humerus fracture surgery, this is unlikely to have affected the power of our matched analysis because patients without calculable MELD scores are likely to be more similar from a demographics and comorbidities standpoint to our control group of patients with a MELD score ≤10. Finally, we were unable to differentiate between anatomic and RTSA because they are assigned the same CPT code. However, the majority of arthroplasty cases included in our study are likely RTSA given that anatomic SA makes up less than 5% of all arthroplasties currently performed for PHF.[33]

TABLE 4

ORIF Versus HA in Propensity-Matched Patients With Chronic Liver Disease

	ORIF (n = 45)	HA (n = 45)	*P*
Age (years)	75.1	72.9	0.318
Male (%)	40.4	40.4	1.000
BMI	27.2	30.0	0.220
ASA greater than 3 (%)	19.2	23.1	0.631
Elective (%)	30.0	28.9	0.906
Any adverse event	30.8	53.9	0.017
30-day mortality	5.8	1.9	0.308
30-day reoperation	7.7	5.8	0.696
30-day readmission	11.8	10.3	0.821
72-hour transfusion	19.2	46.2	0.003
Major systemic complications	3.9	3.9	1.000
Minor systemic complications	9.6	1.9	0.093
Local complications	0.0	0.0	n/a
Operative time	100.5	138.2	<0.001

In conclusion, patients with a MELD score greater than 10 who undergo surgical management of PHF have a significantly elevated risk of surgical complications, blood loss requiring transfusion, readmission, and death. In this study, ORIF was associated with a lower transfusion rate and shorter operative time than arthroplasty options, but treatment modality was not found to significantly affect the risk of short-term surgical complications or 30-day mortality in PHF patients with CLD.

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